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CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. XXXIX.

FURTHER OBSERVATIONS ON THE MYXOBACTERIACEÆ.

ROLAND THAXTER.

(WITH PLATES XXX-XXXI)

IN a paper published in the GAZETTE[1] a few years since the writer presented certain notes concerning a curious group of Schizomycetes, which, from the fact that their life cycle is divided into two definitely recurring periods—one of vegetation, the other a period of fructification or pseudo-fructification through the simultaneous and concerted action of numerous individuals—was thought to be sufficiently well characterized to warrant the separation of its members as a distinct order. The name Myxobacteriaceæ was selected as an appropriate designation for them, in view of the very striking similarities which become evident when one compares the life cycle just mentioned with that of the Mycetozoa; the general characteristics of the two periods being, in either case, practically identical, except for the differences presented by the cell structure of the individual organisms concerned. Since the publication of the paper referred to, the remarkable nature of this resemblance has been further enforced through the appearance of a recent paper by Dr. Zukal[2], in which, under the title "Myxobotrys variabilis als Repräsentant einer neuen Myxomyceten Ordnung," he gives an account of a singular plant, at least very like *Chondromyces crocatus* of my former paper, the characters of which are in his opinion so similar to those of the Mycetozoa that he does not hesitate to place the organism in question near Ceratiomyxa among the "Exosporeae." The vegetative mass of Myxobotrys is held to be a true plasmodium which is said to ingest its food like the plasmodium of a myxomycete, and in a similar fashion rids itself of all foreign matters before rising to form its fructification; the gelatinous matrix about the rods being looked upon as hyaloplasm; while the rod-like structures are described as "microsomata" imbedded in it. It is further stated that, as the plasmodium rises to fructify, the microsomata suddenly disappear and are replaced by numerous long cylindrical filaments, and that these same filaments fill the "spores" at maturity, winding about in their interior.

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[1] BOT. GAZ. 14: 389. 1892.

[2] Berichte d. d. bot. Gesell. 14: 340. 1896.

In a more recent "Notiz zu meiner Mittheilung über Myxobotrys variabilis" Dr. Zukal calls attention to the identity of this species with *Chondromyces crocatus*, making further suggestions as to its probable synonymy which will be mentioned below. He further remarks that, strange as it may appear, the present writer's view as to the schizomycetous nature of this organism is worthy serious consideration, although he further asserts his own disbelief in the truth of this assumption, as well as his adherence to the opinion expressed in his first paper, namely, that the organism in question belongs not to the bacteria, but to the Mycetozoa. In view of the striking and important differences which would seem to distinguish Myxobotrys, as described by Dr. Zukal, from any member of the Myxobacteriaceæ with which I am familiar, it is perhaps not altogether safe to assume its identity with *Chondromyces crocatus*, although the two appear to approach so closely in general habit. If, however, we assume this identity and admit for the moment the correctness of Zukal's observations, it must be confessed that his interpretation of the development described by him is quite as remarkable as the facts themselves. A true plasmodium, consisting of a matrix of hyaloplasm wholly destitute of nuclei and apparently of any structure whatever, in which are embedded rod-like microsomata capable of entering upon an independent existence when separated from the plasmodium, as well as possessed of a Beggiatoa-like power of locomotion and a capacity for indefinite multiplication by fission, coupled with a faculty of transforming themselves suddenly into slender filaments, would be sufficiently singular, even were not these same "microsomata" demonstrably cells, similar to the cells of other schizomycetes; and did not these cells, like other bacteria, produce, in a whole series of forms, definitely differentiated spores capable of germination.

That all plasmodia, as suggested by further observations recorded in the "Notiz" just mentioned, are likely to prove similar to the vegetative mass of the Myxobacteriaceæ, and that they will be found to possess a mode of increase, hitherto overlooked, by means of bacteria-like energids, seems unlikely in view of the well known fact that the energids of true plasmodia are potential amœbæ. It is hardly necessary to remark that I am unable to agree with Dr. Zukal in considering the Myxobacteriaceæ members of the Mycetozoa; and further observation of them during the past five years, during which certain species, including *C. crocatus*, have been kept in constant cultivation in my laboratory, has served fully to confirm the correctness of the views previously published in the GAZETTE. Having been occupied during this time with other matters, I have been unable to pay special attention to the group; yet have succeeded in accumulating a certain amount of new material, and have made a few additional observations in connection with the development of its members, the most important of which relate to the sporulation and spore germination of the species of Myxococcus; both which matters were left undetermined in my previous paper. The present note is therefore offered as a further contribution towards a knowledge of the species, as well as of the development of a group of organisms which, as is evidenced by its entire omission from a work like the *Pflanzenfamilien* of Engler and Prantl, does not appear to have received the recognition it well merits. That the family, as predicted in my former paper, is likely to prove by no means numerically insignificant, is indicated by the additions enumerated below, which have for the most part made their appearance by accident, as it were, on laboratory cultures designed for other purposes; and it seems probable that any systematic attempt to enlarge our knowledge of the species could hardly fail to produce interesting results.[3]

It may be remembered that, in arranging the nine species which formed the nucleus of the order, two sub-groups were distinguished; the one including in the single genus Myxococcus all those forms in which the individuals become transformed into definite spores during the period of fructification; while all the remaining forms were included in the two genera Chondromyces and Myxobacter; the individuals in both these instances becoming encysted *en masse*, without being converted into definitely formed spores. In the first category those species in which the spore mass is permanently encysted or definitely coherent at maturity were further distinguished from those in which it soon becomes deliquescent, while in the second category those forms which produce their cysts free in the air (Chondromyces) were separated from those in which the latter are formed embedded in a gelatinous matrix, the two species included in the last mentioned class being placed in the genus Myxobacter, which, as will be presently seen, may be referred with little doubt to Schroeter's Cystobacter.

Although all of the forms described below fall under one or the other of the above categories and no new generic types are included among them, the gross structure of the fructifying condition in several of them presents points of no little interest. In the Myxococcus group, for example, the species previously enumerated were all characterized by a practically sessile habit, and in the absence of a knowledge of their complete life history their close relationship to the more highly developed cystophore-producing forms might well have been questioned. The discovery, however, of the species subsequently described as *Myxococcus stipitatus* serves more definitely to indicate the close relationship between the two groups, since in this instance the spore mass is raised above the substratum on a well developed stalk, corresponding exactly in structure and method of formation to the often highly differentiated cystophores characteristic of nearly all the species of Chondromyces; the only difference being dependent on the fact that in the one case the ultimate mass or masses of individuals become encysted as such, while in the other they form an eventually deliquescent spore mass. A further indication of this relationship is also found in the characters which distinguish *Myxococcus cruentus*, the cysts in this species being very clearly differentiated, with a well defined wall surrounding the mass of spores within, which are themselves embedded in a stringy, coherent though scanty matrix that recalls the corresponding condition found in the cysts of Chondromyces. The spores, moreover, are not as well developed as in the other species of Myxococcus, and seem to suggest a transitional form between a slightly modified rod, such as occurs in the cysts of Chondromyces, and a typical spore like that which is found, for example, in *Myxococcus rubescens*. The general habit of the species closely resembles that of Cystobacter as below emended; and, were it not for the definite spores, might readily be included in that genus. In this connection it may be mentioned, moreover, that an examination of the contents of mature cysts of *Cystobacter fuscus* shows that the rods in this case are more definitely modified than in the species of Chondromyces; their walls being visibly thicker and their contents enclosing the same definitely formed nucleus-like body described below as characteristic of the developing spores of Myxococcus. It should be mentioned, however, that I have not yet had an opportunity of reexamining fresh material of the other species of Myxobacter, in order to ascertain whether they exhibit similar modifications.

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[3] Since the present paper was in press Messrs. Pound and Clements in their "Rearrangement" of the North American Hyphomycetes (*Minnesota Botanical Studies*, 44) have referred the lichenicolous species of Illosporium to the Myxobacteriaceæ. The species of this genus, however, are semi-sclerotic conditions of hyphomycetous fungi, which, in some instances at least, are connected with species of Nectria, and in no case can be mistaken for Myxobacteriae. Why these authors retain the genus Stigmatella in their rearrangement is not apparent.

The most important fact, which further examination of the sporiferous forms has served to determine, is connected with the process of spore formation and germination, matters which in my former paper were left in doubt from lack of exact observations; certain appearances which one often sees in the rising masses of spores, having, in the first instance, led to the erroneous suggestion there made that they were produced in chains, while the process of their germination was also left undetermined. Further and more extended examination of these processes in pure cultures of *Myxococcus rubescens* shows that my previous conclusions in regard to these matters are not in accordance with the facts, since the phenomena in either case prove to be such as would naturally be associated with the development of organisms of this nature.

As was mentioned in my previous account, sporulation appears invariably to take place gregariously, if one may use such an expression to indicate that isolated rods have never been seen to become thus transformed. The impulse to sporulate thus seems to be, as it were, contagious, and takes possession of a large number of rods simultaneously, which, in their turn, exercise a similar influence on other rods in their more immediate vicinity; so that a condition of things exists at this period which serves still further to accentuate the remarkable correspondence between the Myxobacteriaceæ and the Sorophoreae or pseudoplasmodium-forming Mycetozoa. From the fact, therefore, that sporulation only occurs in the rising rod mass, and that it takes place more or less continuously, in a narrow zone only, below the spore mass, which for a certain period is thus constantly being augmented from below, direct observation of the process, as for example in Van Tieghem cells, is almost impossible. It is therefore only by removing from pure cultures and crushing whole guttulae that the successive stages can be obtained. Both rods and spores are in general so minute and become so promiscuously intermingled by this treatment that, except in very favorable instances, the true nature of the process is not at once apparent, although, when once ascertained, it has been readily demonstrated in all the species examined. By removing and crushing guttulae of *Myxococcus rubescens*, for example, which have formed on agar in pure cultures, selecting preferably such as have recently begun to rise from the substratum, it is not difficult to obtain in abundance all stages illustrating the process of sporulation; and by staining the material with Delafield's haematoxylin, or with eosin, the mature spores which resist stains are at once differentiated in the preparation from the immature conditions. It may be thus definitely determined that sporulation consists in the direct transformation of single rods into single spores. By a gradual inflation, involving a corresponding shortening of the rod in the direction of its long axis, even the longest individuals eventually assume a spherical form, and through the deposition of material on the inner surface of their walls are gradually converted into thick-walled refractive spores. The successive steps in this transformation may be more readily understood by reference to *fig. 36* (*a–j*), and it may be mentioned that, as is indicated in the figures, a marked enlargement is first apparent at one end of the rod, the progressive transformation gradually involving the whole cell. As in other members of the group, the rods, when they run together to sporulate or to produce cysts, become thickened and somewhat shortened, and the more densely granular portion of their contents tends to collect in somewhat definite masses. Even before the rods have begun to show the terminal inflation just mentioned, one of these masses towards the extremity of the cell may be seen to be distinctly larger than the rest, which tend to disappear as the transformation of the rod progresses; the larger mass becoming more and more distinct and clearly defined, taking a deep stain with either eosin or haematoxylin. As the spore assumes a more rounded form this deeply staining mass comes to occupy a central position, and has the appearance of a well defined nucleus-like body (*h* and *i*), which continues to stain readily and deeply until the wall becomes so thick that the whole spore remains bright and refractive and impenetrable by stains, except after they have acted for a considerable time.

The occurrence of this nucleus-like body in the spores of Myxococcus led me to examine more carefully the conditions found in the rods of Chondromyces while becoming encysted, and in these instances also the granular more deeply staining portions of the cell contents were found to collect in more or less definitely circumscribed masses. In Chondromyces this mass, though more frequently single, was found to be generally elongate, occupying a central or usually somewhat lateral position (*fig. 15*). In the rods which compose the ascending "pseudoplasmodium" in this genus, the granular masses are very readily demonstrated by staining, and have in general the appearance represented in *fig. 14*, a small mass being commonly distinguishable at either end of the cell, while a much larger and more irregular one is apt to occupy a central position. In *Cystobacter fuscus*, on the other hand, a portion of the more deeply staining contents, as has been previously mentioned, was found to become definitely aggregated into a well defined nucleus-like body corresponding exactly in its general appearance to that of the sporulating forms just described, an accompanying thickening of the wall being in many cases distinctly visible.

Such transitions between a slight and a complete transformation in the rods at the period of fructification are doubtless correlated with an inverse differentiation of the cyst, the most perfectly formed spores being those characteristic of deliquescent guttulae, while the least well marked differentation of the individual rods occurs in forms like *Chondromyces crocatus* in which the cysts reach a maximum development.

At the time when my first notes were published no satisfactory data had been obtained in regard to the germination of the spores in any case. In cultures of Myxococcus made from material which had been kept air dry for several months, the spores when placed in a nutrient medium gradually assumed a short stout rod form; but no separation of this body from the spore wall was noticed nor was any further development of the rods by fission seen, although both may have been overlooked. Recently, however, by cultivating in Van Tieghem cells the spores of *M. rubescens* taken from pure agar cultures, I have repeatedly obtained abundant germinations and have been able to follow the whole process with a $\frac{1}{16}$ oil immersion. The most convenient mode of procedure for this purpose I have found to be as follows. A small amount of the spore-material, which is easily obtained free from rods when taken from pure agar cultures, was spread near the center of a sterilized cover glass; and when thoroughly dried on, so that the spores adhered firmly, was covered with a thin slice of nutrient agar transferred directly from the surface of a sterilized agar tube. The coverglass was then mounted on the cell in the ordinary fashion, a small amount of water containing unicellular algæ being added within it to furnish moisture and oxygen. The spores were thus firmly fixed in definite positions on the under side of the cover and could be readily examined directly with the immersion objective. In these cultures the germinations began to be visible in from one to two weeks, seven days being the shortest period within which they occurred; and in all cases they were of a single type, no instances being noticed in which the spores underwent the gradual change of form above described, which on the assumption that no separation of the rod from the spore wall occurred, must, I think, be considered an abnormal phenomenon.

The first indication of germination, as shown by preparations which, since they could not otherwise be stained, were made directly from the Van Tieghem-cell cultures, consists in the slight enlargement of the spore and the recovery of its power quickly to absorb stains. Such deeply stained spores are conspicuous in a field, contrasting with the still refractive and wholly colorless ones in which germination has not yet commenced. The walls of the spores thus stained (*fig. 34*) appear as if irregularly corroded by absorption from within, and eventually become comparatively thin, often more so at one or two definite points than elsewhere. At such a thin point a protrusion is then seen, which gradually increases, and at the same time the outline of a stout rod, sometimes bent or irregularly swollen, becomes more and more distinct within the spore-wall (*fig. 35*). The emerging rod elongates with considerable rapidity, until it becomes about twice as long as the diameter of the spore. In several cases it was then seen to slip out free from the spore wall (*fig. 35*, *h*, and, four minutes later, *i*) which remains for a time as an empty shell, but gradually dissolves and disappears. More commonly, however, the emerging rod does not escape from the spore wall, but remains attached to the latter, being apparently fixed within it, elongating and dividing as is indicated in the series of figures (*c–g*) which represent the successive stages in the development of such a rod. In very many cases the emerging rod may be seen, as in *j* and *k*, to have penetrated the spore wall on both sides, so that two free ends project and continue to grow and divide as usual till the old spore wall disappears through absorption. That such appearances do not represent accidental superpositions, I have been able to determine to my own satisfaction.

The addition of the following species, the number of which might be augmented by others that from lack of proper material I have been unwilling to publish, more than doubles the number of representatives of the group formerly enumerated and serves to enforce with even greater emphasis than was before possible the fact that the course of development of these organisms forms a distinct departure from that of other Schizomycetes, in that their life cycle, as has been pointed out, is divided into two distinct periods; the one of vegetation, the other of fructification or pseudo-fructification resulting from the concerted action of many independent individuals toward this very definite end. This view is here reiterated for the reason that in one of the few references to the group that have come to my notice since the publication of my first paper, it is held that the aerial character of the cysts, and not the circumstance just mentioned, should be regarded as the crucial point of difference between the Myxobacteriaceæ and other Schizomycetes. As a matter of fact, the cysts or spore masses are not always produced vertically free from the substratum; and were forms discovered, as they well may be, which reached maturity in water or embedded in the nutrient matrix, they would still be clearly distinguished as above indicated.

Among the forms described below belonging to the genus Chondromyces the most striking is that which I have called *C. apiculatus*, an African species distinguished from its ally, *C. crocatus*, by a curiously well defined and constant specific character, which, though quite as reliable as a well marked difference in spore-form would be in the higher fungi, is here dependent on a slight variation in the movements of the individuals composing the ultimate rod masses during the maturation of the cysts, the invariable recurrence of which gives to the mature cysts a specific form. This form results from the fact that the cyst, when it has received all the rods destined for it, becomes at first fusiform, as in *C. crocatus*, the extremities, however, being more attenuated than in this species; but while in *C. crocatus* the mass of rods composing it, together with the film of hardened gelatinous material which has been secreted around them, gradually assumes the subconical shape characteristic of the species, the individuals in the cyst of *C. apiculatus* migrate from each extremity towards the center, this movement taking place within, and without involving the surrounding membrane which is thus left empty at each end, the empty portions corresponding to the shrivelled appendages which distinguish the mature cysts.

Among the other species the most interesting are perhaps the *Cystobacter erectus* and *C. fuscus* of Schroeter. Of these the former (*figs. 16–19*), although undoubtedly a Chondromyces, proves quite distinct from *C. aurantiacus* with which I was formerly inclined to unite it; while the latter, since it is doubtless congeneric with the species of my own genus Myxobacter, may be considered as the type of the genus Cystobacter, a name which, of course, antedates my own.

Chondromyces apiculatus, nov. sp. *Plate XXX, figs. 1–15.*—Cystophore stiff, rigid, simple, rarely sparingly branched, bearing the single spherical cyst-mass terminally. Cysts very variable in form, shape and size, cylindrical to broadly turnip-shaped, the young cysts fusiform or nearly so, the rods retreating from each end towards the center and leaving behind a shriveled membrane forming a basal and terminal appendage, the latter longer and pointed. Color bright orange. Rods 1 by 3–20μ, sometimes longer. Head of cysts 136μ, average about 200μ. Cysts, turnip-shaped form, average about 35μ broad by 28μ long; cylindrical form, average 35 by 18μ. Cystophores about 500–1000μ in height. All dimensions subject to great variations.

On dung of antelope from Liberia, Africa.

Two or three cystophores of this striking species made their appearance on some antelope dung sent me from Africa, which I owe to the kindness of Mr. F. C. Straub. Having been successful in propagating it from these original specimens I have kept it in constant cultivation for more than a year, and have thus been able to determine the constancy of the characters which separate it from its nearest ally, *C. crocatus.* Its general color is somewhat more orange and less yellow than that of the last mentioned species, and though rarely branched it never develops the highly differentiated cystophores so characteristic of this species when growing under favorable conditions. The head is almost invariably solitary under the most favorable conditions, and the mature cysts are always characterized by the peculiar shrivelled appendages to which reference has already been made above. The variations in the form of the cysts is very great, the most typical and striking having the turnip or onion-shape represented in *figs. 5, 10, 11.* The cysts not infrequently fuse laterally while in process of formation so that conditions similar to those represented in *figs. 8, 12* are sometimes found, which have resulted from the fusion of two and three cysts, respectively. The germination of the cysts is as readily observed as in *C. crocatus,* but, unlike that species, takes place not only normally at the base, but also at the apex, as is represented in *fig. 13.* The species never grows as readily or as luxuriantly as *C. crocatus,* and I have found great difficulty in inducing it to grow pure on nutrient agar, on which it develops very slowly, and seldom produces cysts and cystophores.

Chondromyces gracilipes, nov. sp. *Plate XXXI, figs. 20–24.* —Color orange red. Cystophore simple, tapering distally to a pointed apex, rigid and persistent on the substratum. Cysts solitary, terminal, oblong to oval, rounded distally, somewhat flattened basally, caducous. Rods minute, slender, 0.6 by 2–5μ. Cystophore 25–40μ high. Cysts average about 25 by 35μ.

On rabbit dung, Arlington, Mass.

This minute and well marked species made its appearance on a laboratory culture of rabbit dung which it covers with a powdery orange coating. It appears to be constant in its characters, and is abundantly distinct from any of the other known species of the genus.

Chondromyces erectus (Schroeter). *Plate XXXI, figs. 16–19.*

Cystobacter erectus Schroeter, Kryptogamenfl. v. Schlesien, III Band, 1 Lief. p. 170.

Color orange red turning to chestnut brown. Cystophores fascicled, united at the base in groups, above simple or sparingly branched, bearing a single terminal broadly oblong or rounded cyst on a broad base. Cystophores withering at maturity so that the cysts often appear sessile. Rods 0.9 by 2–5μ or longer. Cysts average about 50 by 40 μ. Cystophore 60–300 μ or more in height.

On horse dung in laboratory cultures. Cambridge, Mass.

This species has appeared repeatedly in laboratory cultures within the past few years and seems abundantly distinct from its nearest ally *C. aurantiacus*, its fascicled habit, single terminal cysts, and the chestnut brown color of the latter when mature serving to distinguish it readily from any of the varieties of *C. aurantiacus* with which I am familiar. The cysts of the latter sometimes become brown with age, but in the present instance they assume this color as soon as they are mature.

CHONDROMYCES AURANTIACUS (Berk. & Curtis) Thaxter.

In my former paper on the Myxobacteriaceæ it was suggested that this species was probably synonymous with *Stilbum rhytidospora* figured by Berkeley and Broome in their Fungi of Ceylon, as well as with the *Polycephalum aurantiacum* of Kalchbrenner and Cooke described from African specimens. Although this suggestion was based only on an examination of the figure of the former and description of the latter, it proves to have been correct according to the statement of Massee,[4] who has examined the types of these two forms, as well as that of *Stigmatella aurantiaca*. The synonymy formerly given with a query may therefore be considered correct. The species has been found commonly in many localities and has been sent me from Ohio by Professor Morgan. It has also made its appearance in abundance and in the

[4] Grevillea **21** : 124.

typical form on the same antelope dung from Africa which yielded *C. apiculatus*, and under conditions that made its African origin unquestionable. The species is totally distinct from *C. crocatus*, with which Dr. Zukal would unite it, both in the form and character of its cysts and cystophores, as well as in its color, and is in general very constant, although what appears to be a variety of the same form accompanied the Liberian material and differs from the fact that it is larger and often copiously branched, one "individual" thus producing a number of heads.

CYSTOBACTER FUSCUS Schroeter. *Plate XXXI, figs. 37-39.*

Schroeter Kryptogamenfl. v. Schlesien, III Band. 1 Lief. p. 170.

Color orange red becoming chestnut brown, the rising rod masses pale flesh colored. Cysts formed by the separation of the parts of a more or less convoluted rod mass, nearly spherical to long-oblong or irregularly elongated at maturity, surrounded by a gelatinous matrix, heaped together or lying in one plane on the substratum, each cyst surrounded by a thin, papery, separable chestnut-brown wall; when dry dark dull red. Rods slender, elongate, 0.6 by 5-12 μ. Cysts 50-150 by 50-70 μ.

On dung of rabbits from southern California.

This interesting form made its appearance in abundance, together with *Myxococcus coralloides*, *Pilaira Cesatii*, and several other interesting plants, on rabbit dung from southern California, for which I am indebted to Mr. F. H. Billings. It is a conspicuous species, growing and producing its cysts readily on agar, and seems to correspond in all essentials to the generic type which I formerly called Myxobacter from the fact that its cysts are embedded at maturity in a mucus envelope. Its characters seem to be so nearly identical with those of Schroeter's species that I have no hesitation in referring it to *C. fuscus*, which, it may be remarked, was also found on the same substratum. Assuming that this reference is correct, Myxobacter must be superseded by the earlier name, under which should be included *Cystobacter aureus* and *C. simplex*.

Myxococcus stipitatus, nov. sp. *Plate XXXI, figs. 30-33.*

Color white to pink or flesh color. Spore mass becoming deliquescent, subspherical, formed at the apex of a well developed stout stalk which raises it free above the substratum. Rods 0.5-07 by 2-7 μ or longer. Spores oval, 0.8-1.2 by 1-1.15 μ. Spore mass about 175 μ in diameter. Stalk 100-200 by 30-50 μ.

Dung of sheep, pig, and other animals. Cambridge, Mass.; Kittery Point, Maine; Burbank, Tennessee.

This striking form has made its appearance not infrequently on laboratory cultures and grows luxuriantly on nutrient agar, although it does not fructify on this substratum as readily as the sessile species. The form obtained on pig dung at Burbank, Tenn., was distinctly smaller in habit and milky white in color; but cultures of this variety on agar reverted to the ordinary pinkish form from which it can hardly be distinct. As already mentioned, the stalk is formed in the same way that the cystophores of Chondromyces are produced, and is persistent after the spores have separated from it.

Myxococcus cirrhosus, nov. sp. *Plate XXXI, figs. 25–27.*

Color pale reddish or flesh colored. Spore mass more or less elongate, erect, the base slightly swollen, the distal portion tapering to a rounded apex. Spore irregularly spherical, about 1 μ in diameter. Rods 0.8 by 2–5 μ or longer. Spore mass 50–100 μ high, about 20 μ in diameter at the base.

On grouse dung from Readville, Mass.

This form appeared on a laboratory culture and is so minute and inconspicuous from its pale color that it is seen with difficulty, the more so since the bases of the spore masses are usually more or less embedded in the substratum. The spores although somewhat loosely coherent at maturity do not form a deliquescent mass, so that the species is evidently allied to the section of the genus which includes *M. coralloides.*

Myxococcus cruentus, nov. sp. *Plate XXXI, figs. 28–29.*

Color deep blood red. Cysts regularly spherical, surrounded by a more or less well defined rind or wall within which the spores are embedded in a scanty and amorphous matrix. Rods 0.8 by 3–8 μ. Spores oval or irregularly oblong, 0.9–1 by 1.2–1.4 μ Cysts 90–125 μ in diameter.

On cow dung, Burbank, Tennessee.

This species was found in woods covering the substratum with a blood red coating resembling some dark red Nectria. The cysts are densely aggregated, remarkably uniform in shape and size, and are peculiar from the presence of a moderately well defined wall to which attention has been called above. The spores are more than usually irregular in size and form, and are less well defined than in the other species, resembling in some respects the thickened individuals which occur in the cysts of Chondromyces. The species was not cultivated, and no satisfactory material of its vegetative condition was obtained

CAMBRIDGE, MASS.

EXPLANATION OF PLATES XXX AND XXXI.

The figures are from ink drawings reduced about one-fourth by photolithography. The letters and numbers refer to the Zeiss or Leitz objectives and eyepieces used in making the original drawings. The approximate magnifications in diameters of these combinations, allowing for projection, are (in the original) as follows: A, oc. 4, 180 : C, oc. 2, 230 : C, oc. 4, 400 : D oc. 2, 380 : D, oc. 4, 700 : $\frac{1}{16}$ (oil), oc. 4, 1900 : $\frac{1}{16}$ (oil), oc. 12, 3300.

Chondromyces apiculatus Thaxter.

FIG. 1. Rising rod mass. A 4.

FIG. 2. Branching cystophore, the cysts just beginning to bud out from right head. A 4.

FIGS. 3–4. Typical cystophores with cysts in different stages of development. A 4.

FIG. 5. Cystophore bearing mature cysts of the turnip-shaped type. A 4.

FIG. 6. Young cyst before the rods have retreated from either end. D 4.

FIGS. 7–12. Mature or nearly mature cysts, *figs. 10, 11* of the turnip form, the rest of the subcylindrical type; *fig. 8* showing the union of two and *fig. 12* of three cysts by lateral fusion. All D 4.

FIG. 13. Cyst "germinating" at both ends in the normal fashion. D 4.

FIG. 14. Rods from rising rod mass, stained with Delafield's hæmatoxylin. $\frac{1}{16}$, 12.

FIG. 15. Encysted rods from mature cyst, stained with hæmatoxylin. $\frac{1}{16}$, 12.

Chondromyces erectus Thaxter.

FIG. 16. Cystophores bearing mature cysts showing habit. C 2.

FIG. 17. Young cystophores on which the cysts are just beginning to form. C 2.

FIG. 18. Mature cyst isolated. D 4.

FIG. 19. Group of rods. $\frac{1}{16}$, 4.

Chondromyces gracilipes Thaxter.

FIG. 20. Mature cystophores and cysts. C 2.

FIGS. 22–23. Mature cystophore and cyst. D 4.

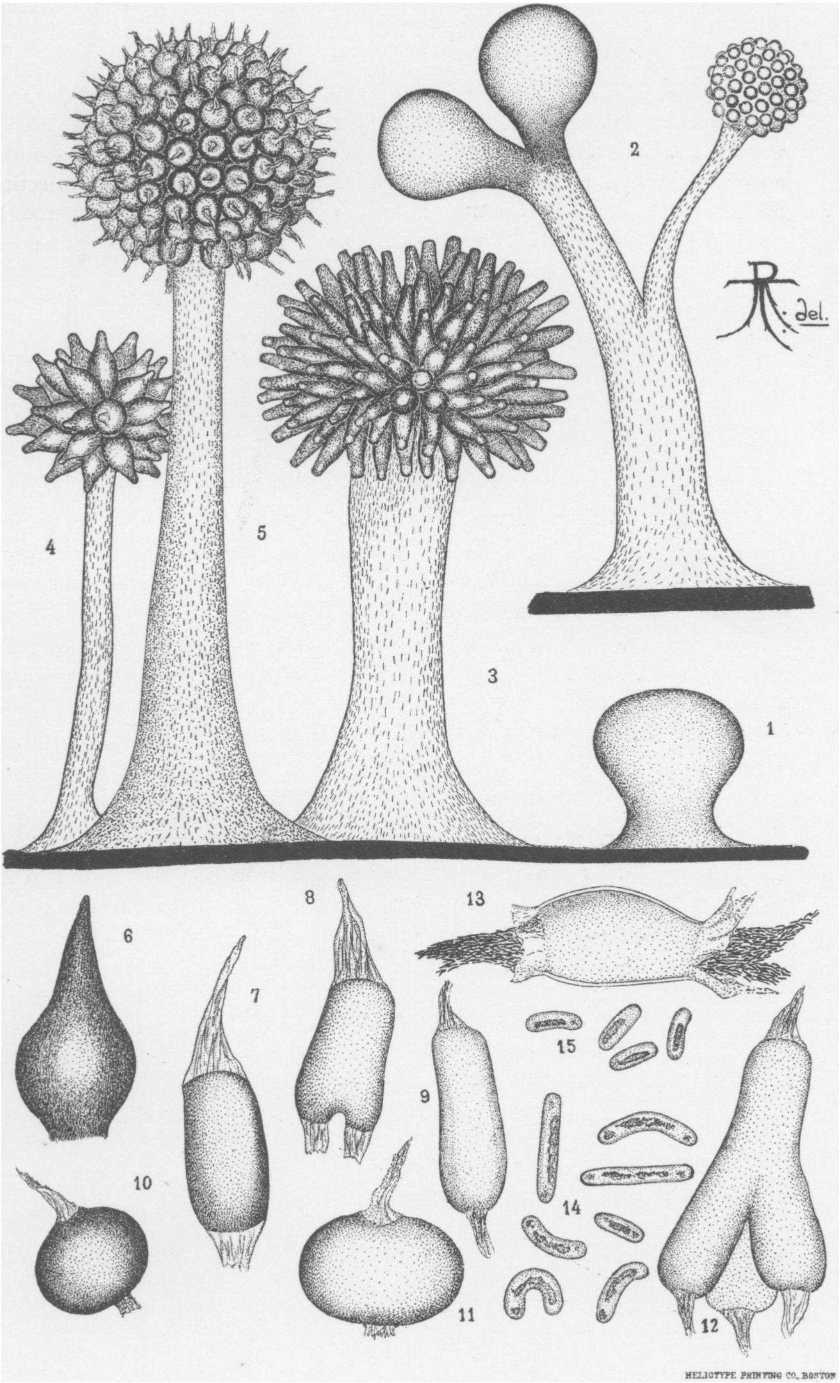
FIG. 24. Group of vegetative rods. $\frac{1}{16}$, 4.

Myxococcus cirrhosus Thaxter.

FIG. 25. Three mature spore masses. C 4.

FIG. 26. Group of rods. $\frac{1}{16}$, 4.

FIG. 27. Group of spores. $\frac{1}{16}$, 4.



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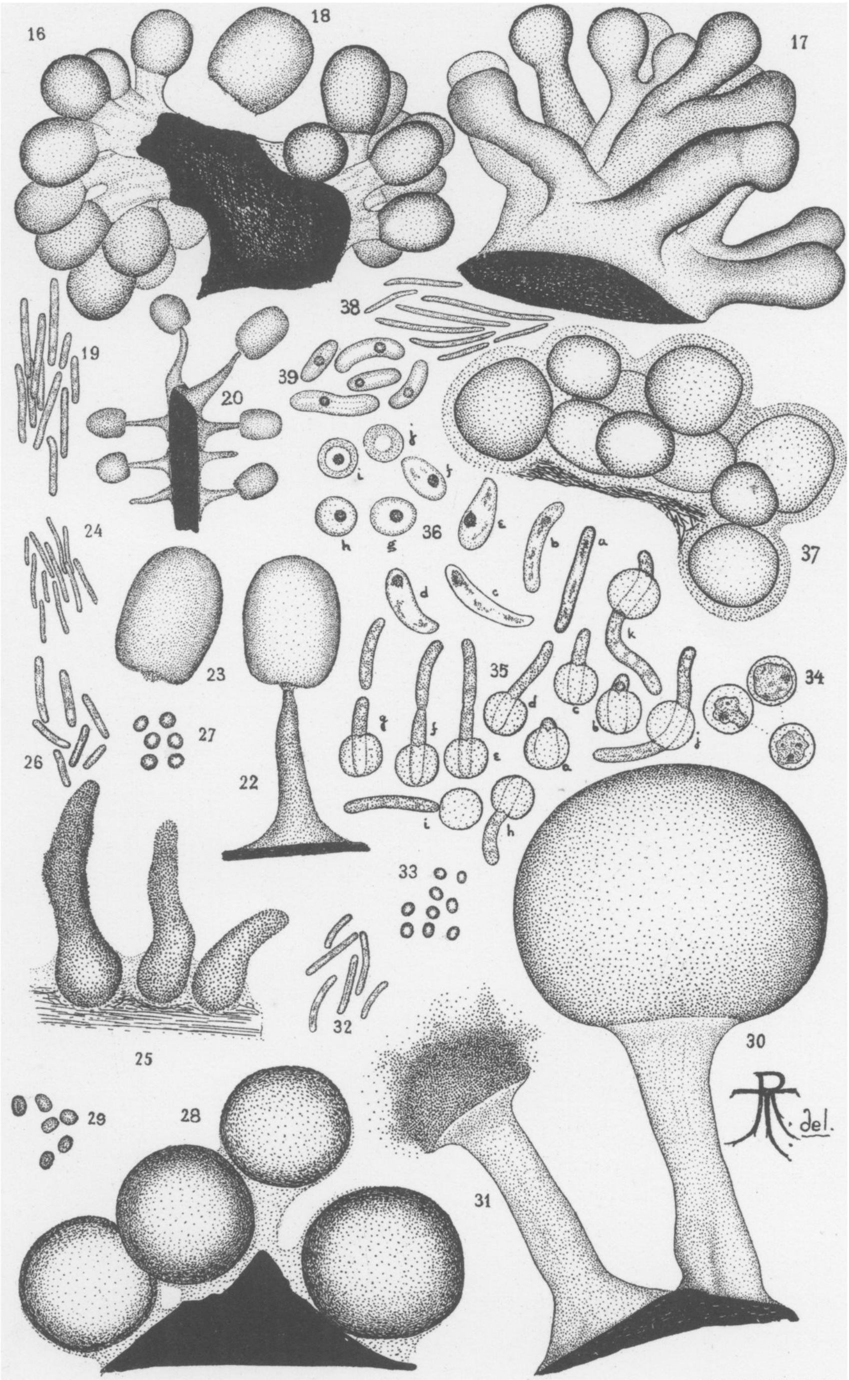
THAXTER on MYXOBACTERIACEÆ.

BOTANICAL GAZETTE, XXIII. *PLATE XXXI.*



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Myxococcus cruentus Thaxter.

FIG. 28. Group of cysts, that at the left showing thickness of cyst wall. C 2.

FIG. 29. Group of spores. $\frac{1}{16}$, 4.

Myxococcus stipitatus Thaxter.

FIG. 30. Stalk with spore mass still intact. C 2.

FIG. 31. Stalk from which the deliquescent spore mass has been removed. C 2.

FIG. 32. Rods. $\frac{1}{16}$, 4.

FIG. 33. Spores. $\frac{1}{16}$, 4.

Myxococcus rubescens Thaxter.

FIG. 34. Three spores preparing to germinate, stained with eosin, from Van Tieghem cell-culture. $\frac{1}{16}$, 12.

FIG. 35. Different stages in the spore germination; *c–g*, division of rod while still adherent within spore wall; *h–i*, rod escaping from spore wall; *j–k*, rod emerging from spore wall on both sides. Drawn from living material in Van Tieghem-cell. $\frac{1}{16}$, 12.

FIG. 36. Successive stages in spore formation; from preparation stained with Delafield's hæmatoxylin, showing deeply staining nuclear-like body and gradual transformation of rod to spherical spore. $\frac{1}{16}$, 12.

Cystobacter fuscus Schroeter.

FIG. 37. Groups of mature cysts removed from substratum. D 2.

FIG. 38. Vegetative rods. $\frac{1}{16}$, 4.

FIG. 39. Rods separated from mature cysts by crushing, and stained with eosin, a nucleus-like body distinct in each.